York International Corporation

Improving Air Conditioning Efficiency

In 1995, experts in the $22 billion air-conditioning and refrigeration industry predicted that U.S. manufacturers would lose market share because of growing foreign competition. At that time, the United States had a 40-percent market share; however, air-conditioning and refrigeration sales by Japanese manufacturers were also at 40 percent and growing faster than U.S. sales. Worldwide sales were expected to reach $150 billion by 2005 as demand from developing countries increased. The Advanced Technology Program (ATP) established a focused program, "Advanced Vapor Compression Refrigeration Systems," in order to help U.S. manufacturers remain competitive and increase their market share. York International Corporation applied for and was awarded cost-shared funding from 1995 to 1998 to develop a novel cooling coil design and manufacturing technologies that would reduce air conditioner size, improve the unit's efficiency and reliability, and improve indoor air quality. York intended to apply innovative concepts from the automotive air-conditioning industry to large stationary systems in order to capture a wider market share. This was risky, because it meant redesigning the coatings and the shape of the fins and tubes that were used in automotive systems, as well as integrating the systems.

By the conclusion of the project, York had designed a heat exchanger that was 25 percent smaller. The company continued development for another year after the project ended. Although York decided to postpone commercializing the coil technology, the company developed a fin calorimeter that it used for measuring heat transfer and a method to rapidly prototype fins. The company later used the tool and the method in additional research and development efforts that led to commercialized products.

COMPOSITE PERFORMANCE SCORE
(based on a four star rating)
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Research and data for Status Report 95-06-0004 were collected during October 2003.

Improved Air-Conditioning Efficiency Could Maintain U.S. Market Share

In 1995, approximately 40 percent of the estimated $22 billion annual global air-conditioning and refrigeration equipment industry was supplied by U.S. manufacturers. The global market was expected to grow to $150 billion by 2005 as demand increased in developing countries. Innovation and efficiency gains would be key to maintaining and increasing U.S. market share.

Air handling units (AHUs) are a style of air conditioning suited for large buildings. Air conditioners cool and dehumidify air through the use of internal heat exchangers, or "cooling coils," in which liquid refrigerants extract heat from air removed from a populated area, called an occupied space (see illustration of an AHU). Fans blow a mixture of outside air and return air (coming back from the occupied space) onto the coil, located in the AHU. This warm-air mixture is cooled as it is blown over the tubes that contain liquid refrigerant. Metal fins attached to the tubes help to conduct the heat. Cool liquid refrigerant enters the coil tubes, snakes through the coil as it absorbs heat, and exits. Moisture from the warm air condenses on the cool tubes and fins and must be drained. The fan blows cool air from the coil, through the ducts, back to the occupied space.

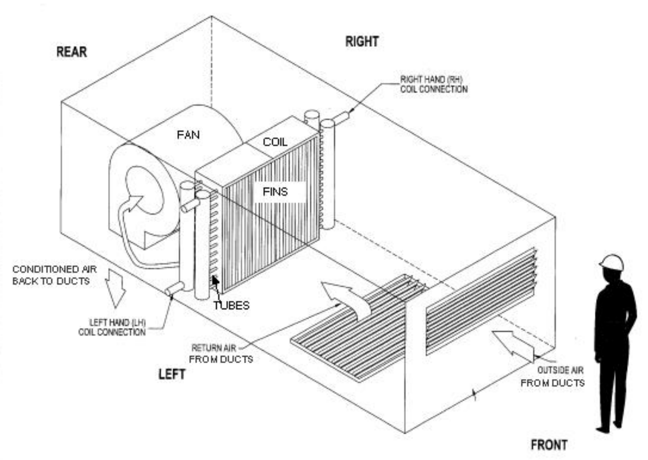

Diagram of an air handler unit. Warm outside air and return air enter from the ducts and blow across the coil, which absorbs heat through the fins and tubes. Cool liquid refrigerant enters the coil tubes from the right-hand coil connection, snakes through the coil, and exits to the left. Moisture from the coil collects and drains down to a pan beneath it. The fan blows cool air from the coil back to the occupied space.

The performance of heat exchangers is restricted by various factors, including the choice of liquid refrigerant, the type of metal used in the tubes, the dimensions of the tubes, and the need to keep air velocity low. In the case of the latter, this is necessary so that condensed moisture and dirt are not blown beyond the coil back to the occupied space, which would lower the indoor air quality (IAQ).

By reducing the coil size and improving its efficiency, a manufacturer could capture more of the large-scale heating, ventilation, and air-conditioning (HVAC) market. Moreover, these improvements could reduce material costs (as a result of producing smaller units), capital costs (by requiring a smaller footprint), electricity costs (by operating more efficiently), and health care costs (by reducing bacteria and moisture reentering the occupied space). The improvements could potentially reach hundreds of millions of dollars annually.

ATP Funding Enables Collaboration

York International Corporation, the largest independent supplier of HVAC and refrigeration products in the United States, wanted to apply recent energy-efficient automotive air-cooling concepts to the HVAC industry. The HVAC industry had not achieved lasting innovations in new technology in the years prior to 1995. For example, they had not experimented with improving the design of heat exchangers or changing the shape of the tube technology used in the units. As a result, they lagged behind the auto industry in cooling efficiency innovation. Furthermore, while high-performance, compact heat exchanger designs that used brazed (hardened) aluminum oval-tube technology were gaining acceptance in the auto industry, there had been no similar innovation in the $2.7 billion commercial and industrial HVAC markets. There were two reasons for this: 1) brazed aluminum offered no cost savings over existing copper technology (because weight savings is not a significant factor in commercial systems), and 2) existing copper systems can be repaired on site, and they work well with heat transfer fluids. These fluids, which include water and brines, are preferred over Freon or other "evaporating refrigerants" in building air supply systems, because a potential leak of water is less hazardous to IAQ. Moreover, interior corrosion of the aluminum results in reliability problems (e.g., clogs and leaks). In order to improve efficiency, York would need to develop new coatings and a new design for the fins and tubes. York would then need to integrate the parts into a single system. The company also planned to reduce the size of the heat exchanger by 25 percent and increase energy efficiency.

Reducing the coil size and improving its efficiency could reduce material costs, capital costs, electricity costs, and health care costs. The improvements could potentially reach hundreds of millions of dollars annually.

If successful, new HVAC systems would require smaller space while maintaining performance, which would reduce capital costs for new systems over time. Furthermore, IAQ would improve as a result of reduced coolant leaks because leaks contribute to odors and bacterial growth. In order to research and test these potential innovations, York submitted a proposal in 1995 to ATP's focused program, "Advanced Vapor Compression Refrigeration Systems." The program sought to support the development of cooling products that were more efficient, less costly, and better performing than the products manufactured by foreign competitors.

York received $1 million in ATP cost-shared funding. The company teamed with the Mechanical Engineering Department at Pennsylvania State University, which provided the concepts for heat exchanger technology and preliminary testing of sample miniature coils. York hired several subcontractors to support specific components of the research plan: Tridan Tool and Die Company (now Tridan International, Inc.) produced fin dies and fin stacks; Timesavers, Inc. provided roughened finishes on fins for initial testing; Materials Science Corporation conducted refrigerant pressure testing; and Automated Test Labs provided final results on thermal transfer and air-pressure drop.

York Develops Challenging Milestones

The York team's objective was to design and manufacture efficient, compact, high-quality, air-cooled, coil-style heat exchanger technology for cooling indoor air. Higher efficiency would result in lower operating costs for users and less adverse impacts on the environment. The smaller units would require less space and would cost less to manufacture. As described below, while York's goals were innovative, the project achieved mixed results due to technical difficulties.

- ***Task***: Reduce the size of the oval copper tubes by 25 percent (internal volume and material content), while maintaining performance, by using a slightly smaller oval-tube design. The goal was to make an aerodynamic shape and increase the exposed surface area relative to volume in order to enhance the heat transfer.
  Results: The team successfully formed oval copper tubes with a 4:1 diameter ratio (i.e., the length of the oval was 4 times longer than its width) and reduced volume for use in 12 prototype coils. The team manufactured oval tubes that were 10 percent more efficient in heat transfer than round tubes of comparable size. However, it was difficult to insert oval tubes into a fin stack. In the assembled condition, the tubes did not align and fit tightly in fin collars.

- ***Task***: Evaluate and select a cost-effective hydrophilic or "wettable" coating to apply to the heat exchanger fins produced by Tridan Tool and Die Company. Minimizing surface moisture retention would reduce the impact on the IAQ, as well as on the health of the building's occupants. The coatings increase the surface contact area of the water droplets to make them flatter; the water then sheets away, similar to a dull finish on an un-waxed car in the rain. As a result, moisture is less likely to blow off the fins into the supply air vent.
  Results: The team tested seven wettable treatment variations and experimented with roughening methods applied by Timesavers, Inc. Early results were favorable, but the coatings degraded over time due to dirt collecting on the surfaces.

- ***Task***: Test the air-pressure drop in the AHU as air moves over standard round coil tubes compared with the new oval-tube design. Reduced air-pressure drop would mean airflow moves freely from the AHU into supply air ducts (with greater energy efficiency).
  Results: Researchers turned the narrow end of the oval tube toward the moving air to reduce wind resistance. Airflow was 15 to 35 percent more efficient with the oval tubes (35 percent at the beginning of a cycle, when coils were dry; 15 percent with wet coils).

- ***Task***: Eliminate refrigerant or brine leaks through machine-driven joint bonding. Eliminating all leaks was important for two reasons: 1) to reduce maintenance costs due to leakage, which had been a chronic problem; and 2) to maintain the chemical uniformity of the fluid refrigerants in order to achieve the system's optimal efficiency.
  Results: Limitations of time and staffing prevented work on the sealed joint beyond the concept stage.

By project end, the York team had successfully designed a new heat exchanger that was 25 percent smaller than standard models. Smaller dimensioned oval tubes maintained the same cooling capacity compared to the standard larger round tubes, but the results with wettable coatings were disappointing. York applied for two patents related to project innovations, but both were denied. However, at the conclusion of the project, there were many tasks left to complete, such as selecting a wettable fin treatment, developing a better way to measure fin wettability, and optimizing tube spacing.

York Derives Lasting Benefit from ATP-Funded Project

During the ATP-funded project, York researchers developed a tool and a method that were of lasting value to the company as they continued their research and development:

- Fin calorimeter, which measures air-pressure drop and heat transfer
- Method for rapidly prototyping fins, which reduces the research and development cycle time for new fins from 24 to 12 months

After the project concluded in 1998, York continued to fund its development of the 12 test oval-tube coils for another year. And as of 2003, the company was still using its fin calorimeter and fin-prototyping method. The company also developed a new commercialized plate fin, called HiQ, using the prototyping method from this project. York uses the fin in its ECO2 rooftop heating/cooling units. The fin has proprietary enhancements that yield approximately twice the heat transfer when compared to a standard wavy or corrugated plate fin. York continues research into wettability today, and this research relies on the knowledge the company gained during this ATP-funded project.

York Decides to Postpone the Coil Project

In 1999, the company made a decision to postpone commercializing oval-tube coil technology. Although commercialization was technically feasible, an economic assessment revealed that it would have cost several million dollars to produce new fin dies and presses to manufacture fins that had the more precisely shaped holes needed to fit the oval tubes snugly. Because the industry was conservative, marketing the new oval-tube design would be challenging. In addition, economists were detecting a slow-down in the U.S. economy in 1999-2000. The company estimates that it would take five years of additional development time to implement the technology.

Conclusion

York International Corporation researched ways to apply successful automotive air-conditioning technology to commercial and industrial air conditioners. Using copper instead of brazed aluminum, York and its subcontractors redesigned the heat exchanger, or "coil," and fin geometry. They also changed the geometry of the tubes from round to smaller ovals in order to reduce coil size and still maintain heat transfer efficiency. They applied wettable coatings to the fins to improve moisture removal and planned to eliminate refrigerant leaks with machine-driven joint bonding. The team successfully produced 12 prototype heat exchangers, which were 25 percent smaller than those in use. Moreover, they demonstrated a 10-percent increase in cooling efficiency with oval tubes compared to standard round tubes.

If successful, new HVAC systems would require smaller space while maintaining performance, which would reduce capital costs for new systems over time.

York has postponed commercializing its novel coil technology due to technical problems that included the fin coatings degrading over time and oval tubes that could not be easily inserted into the fin stacks. York did develop a tool to measure heat transfer and a method to rapidly prototype fins, which the company still uses in the research and development of new products. The project researchers published their results extensively and filed for two patents. York is continuing the wettability research.

PROJECT HIGHLIGHTS
York International Corporation

Project Title: Improving Air Conditioning Efficiency (York Coil Technology)

Project: To develop novel cooling coil design and manufacturing technologies that will reduce the size of air conditioners, improve the units' quality and reliability, eliminate leakage, and improve air quality.

Duration: 9/1/1995-8/31/1998
ATP Number: 95-06-0004

Funding (in thousands):**

ATP Final Cost	$1,068	81%
Participant Final Cost	249	19%
Total	$1,317	

Accomplishments: York demonstrated that oval-tube geometry is 10 percent more efficient for heat transfer than round tubes. Researchers developed a prototype heat exchanger that was 25 percent smaller and had the same heat transfer capability as the standard size. Furthermore, York developed a method and a tool that they still use in their ongoing research and development:

- Method for designing fins, which reduced development time from 24 to 12 months
- Fin calorimeter to measure air-pressure drop and heat transfer

York used the fin calorimeter and new designing method to develop a new fin, called HiQ, which is used in the company's ECO2 rooftop heating/cooling units. This is a plate fin with proprietary enhancements that yield approximately twice the convective heat transfer when compared to standard wavy or corrugated plate fins.

York filed two patents for ideas generated by the ATP-funded project, but both were denied. Furthermore, the company shared its project knowledge through numerous presentations and publications, as listed at the end of this report.

Commercialization Status: Using the methods developed during this project, York developed a new commercialized plate fin, called HiQ. York uses the fin in its ECO2 rooftop heating/cooling units. Its proprietary enhancements yield approximately twice the heat transfer when compared to a standard fin. Due to the prohibitive manufacturing capital cost, York has postponed commercializing oval-tube coil technology.

Outlook: The outlook for this oval-tube coil technology is poor, and York has postponed plans to commercialize it. The company does continue to use its new method for designing fins and its fin calorimeter, which were both developed during the project. Moreover, the company is still pursuing alternate solutions for wettability, building on knowledge gained in this ATP-funded project.

Composite Performance Score: *

Focused Program : Advanced Vapor Compression Refrigeration Systems, 1995

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Tridan Tool and Die Company
Danville, IL

Timesavers, Inc.
Minneapolis, MN

Materials Science Corporation
Fort Washington, PA

Automated Test Labs
Philadelphia, PA

Publications:

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- Kang, H. C. and M. H. Kim. "An Experimental Study on the Thermohydraulic Characteristics of Actual Plane and Strip Fins for Air Conditioner." KSME-JSME Conference Proceedings. Kyungju, Korea, 1996.

** As of December 9, 1997, large single applicant firms are required to pay 60% of all ATP project costs. Prior to this date, single applicant firms, regardless of size, were required to pay indirect costs.

PROJECT HIGHLIGHTS
York International Corporation

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